# THE HIGHLY ADJUSTABLE MAGNET UNDULATOR

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*Abstract*

The highly adjustable magnet undulator is a concept aiming for flexibility and extensive tunability of undulator settings in the linear as well as the helical regime. I report about suggested layout, magnetic simulations.

## INTRODUCTION

Insertion devices such as undulators play and important role in accelerator physics in synchrotron storage rings as well as free electron lasers. Typical use is for creating photon radiation used for various investigations in medicine, biology, crystallography, chemistry, physics and other scientific areas. It can also be used for charged particle beam manipulation together with or without external radiation sources in order to manipulate the particle beam in various ways such in HGHG, EEHG and ORS setups.

The undulators used today are typically limited by their flexibility. This includes having a fixed undulator period, limited tapering options, inability to be quasiperiodically tuned and more. To overcome these limitations I present an idea of a highly adjustable magnet (HAM) undulator.

## UNDULATOR CONCEPT

In the HAM-undulator, magnets are mounted in stacked rotating discs. Each disc comprises a magnet-couple, or magnetic structure pair, where their separations towards each other and the beamline can be adjusted independently. A center cross section view of three discs (in a real undulator many more discs will be implemented), and a front view are depicted in Fig. 1. The electron beam will travel through the center hole of the setup in which a vacuum pipe is implemented.

The system is modular and based on that each disc is identically constructed and then stacked in front of each other and secured in undulator end-plates on each side of the disc stack providing rigid reference surfaces. The full disc setup structure comprising the undulator end-plates and the disc stack can be secured on to a girder.

Since the magnet couples are built into a rotating disc the rotation around the beam axis can be adjusted arbitrary compared to the other discs. Furthermore, depending on the rotation angle between each disc, the helical angle can be changed. Additionally tapering of the magnetic field can be achieved in longitudinal and transversal direction. Tapering effects can also be achieved for helical cases.

The permanent magnet structures are connected to the rotation disc via adjustment means, so that the position of one magnet can be adjusted relative the other permanent magnet structure in the magnet pair. The adjustment means could be arranged to both adjust position of the magnet and to tilt the magnet relative a thought normal to the electron beam. This allow for transverse tapering of the undulator. Longitudinal tapering is achieved by for each disc decrease (or increase) the permanent magnet structure pair separation slightly throughout the undulator.

Each magnet structures in the structure pair could be made up as a simple transverse triple combination of directed permanent magnets to amplify the magnetic flux at the beam position. To alleviate the effect from magnet forces a thin layer of magnet material in longitudinal direction may be added on each magnet structure.

The undulator setup can be controlled by a standard PLC system. Due to the inherent construction no shimming is necessary.

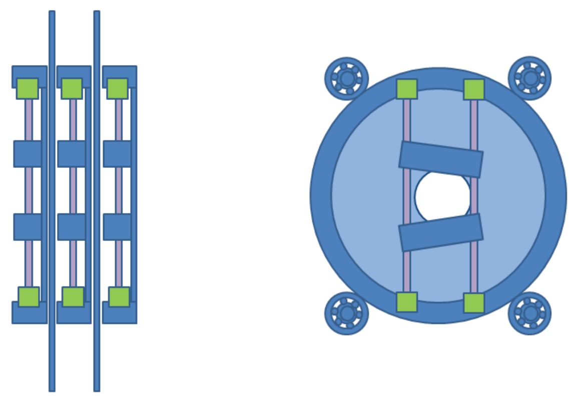

Figure 1: Left: Centre cross section view of three discs (in a real undulator many more discs will be implemented). Right: Front view of one disc with the magnet structure pair on each side of the centre hole.

## EXAMPLE OF USAGE AND BENIFITS

Due to the flexibility of the construction one undulator can be used for many purposes.

- Linearly polarized light can be produced when the magnet couples are aligned with interchanging magnetic field of each disc (up down up etc.).
- Linearly polarized light of longer wavelengths can be produced by pairing rotating discs, as schematically illustrated in Fig. 2 (figure seen from side view with electron beam in centre).
- Circularly polarized light can be produced when the discs are rotated such that an additional rotation angle of up to 90 degrees is implemented for each passed dic, as schematically illustrated in Fig. 3, where figure is depicted from front with electron beam in center. In the figure the rotation angle is called alpha and four magnet structure pairs are implemented.
- Combinations of disc rotations can be implem- ented aiming for producing light with e.g. two



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wavelengths simultaneously or simply for particular phase space manipulation.

- Quasiperiodic settings are possible.
- Longitudinal and transverse tapering is possible for linear as well as helical case.
- Modular design will ease process building and rebuilding the undulator.

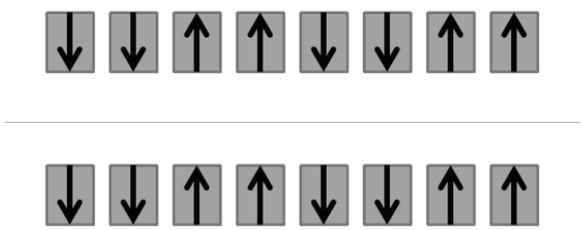

Figure 2: Example of configuration for linearly polarize light with paired configuration which doubles the undulator period. Figure is depicted from the side of the undulator.

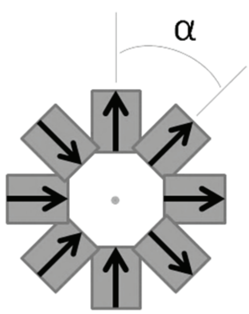


Figure 3: Example of configuration for circularly polarized light configuration as seen where each subsequent disc is rotated with an additional angle α. Figure is depicted as electron beam goes into the paper.

## SIMULATIONS

The HAM undulator setup was simulated with COMSOL doing FEM analysis. Benchmark studies were also made for an APPLE II type undulator for comparison. In the simulation magnets were modeled as permanent magnets lying in pairs and all the magnets were placed in a box of air. For the linear case all the magnets will be aligned as in Fig. 4 where the magnet pairs are indicated with wire frames.

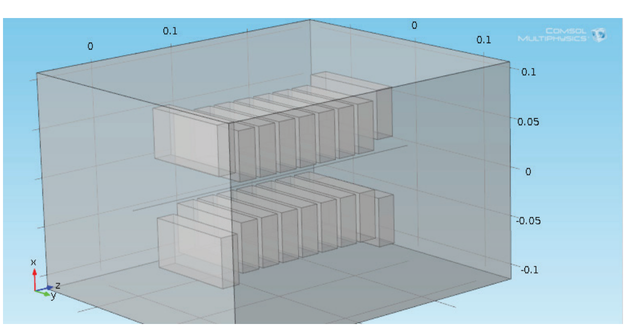

Figure 4: Simulation configuration of linear case illustrating magnet pairs linearly matched within a box of air.

Examples of how the magnets can be aligned for the helical case are found in Fig. 5.

The flux intensity the vector field along the undulator centre axis is indicated with arrows. It is clear that the magnetic field is rotating around the centre beam axis and interchanging as wanted. The worst case scenario with alpha increase 90-degrees scenario is illustrated.

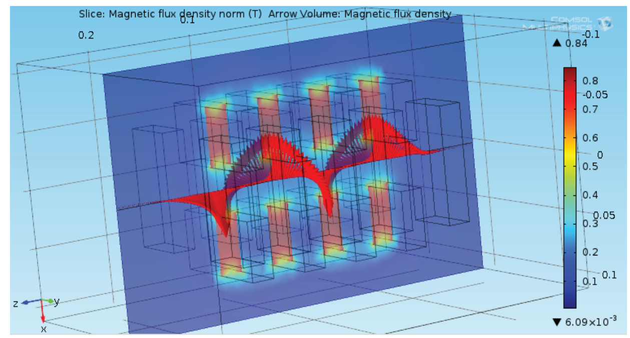


Figure 5: Simulation configuration of maximum circular case illustrating magnet pairs rotated 90-degrees between each disc. The red arrows indicate the flux intensity vector along the electron beam pathway and it is clearly rotating along the trajectory.

## CONCLUSION

The concept and its first simulations show valuable behaviour with unsurpassed flexibility. Especially the ability to change the undulator period within wide ranges and to divide the undulator into sub intervals may be of particular interest. The physical behaviour needs further simulations. Engineering challenges exist but can most likely be overcome by existing technology which could be proven by construction of a test prototype. Patent is pending.

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